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Multi-model evaluation of aerosol optical properties in the AeroCom phase III Control experiment, using ground and space based observations from AERONET, MODIS, AATSR and a merged satellite product as well as surface in-situ observations from GAW sites

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Within the framework of the AeroCom (Aerosol Comparisons between Observations and Models) initiative, the present day modelling of aerosol optical properties has been assessed using simulated data representative for the year 2010, from 14 global aerosol models participating in the Phase III Control experiment. The model versions are close or equal to those used for CMIP6 and AerChemMIP and inform also on bias in state of the art Earth-System-Models (ESMs).
Modelled column optical depths (total, fine and coarse mode AOD) and Angstrom Exponents (AE) were compared both with ground based observations from the Aerosol Robotic Network (AERONET, version 3) and space based observations from the AATSR instrument. In addition, the modelled AODs were compared with MODIS (Aqua and Terra) data and a satellite AOD data-set (MERGED-FMI) merged from 12 different individual AOD products. Furthermore, for the first time, the modelled near surface scattering (under dry conditions) and absorption coefficients were evaluated against measurements made at low relative humidity at surface in-situ GAW sites.
The AeroCom MEDIAN and most of the participating models underestimate the optical properties investigated, relative to remote sensing observations. AERONET AOD is underestimated by 21%+/-17%. Against satellite data, the model AOD biases range from -38% (MODIS-terra) to -17% (MERGED-FMI). Correlation coefficients of model AODs with AERONET, MERGED-FMI and AATSR-SU are high (0.8-0.9) and slightly lower against the two MODIS data-sets (0.6-0.8). Investigation of fine and coarse AODs from the MEDIAN model reveals biases of -10%+/-20% and -41%+/-29% against AERONET and -13% and -24% against AATSR-SU, respectively. The differences in model bias against AERONET and AATSR-SU are in agreement with the established bias of AATSR against AERONET. These results indicate that most of the AOD bias is due to missing coarse AOD in the regions covered by these observations. Underestimates are also found when comparing the models against the surface GAW observations, showing AeroCom MEDIAN mean bias and inter-model variation of -44%+/-22% and -32%+/-34% for scattering and absorption coefficients, respectively. Dry scattering shows higher underestimation than AOD at ambient relative humidity

and is in agreement with recent findings that suggest that models tend to overestimate scattering enhancement due to hygroscopic growth.
Considerable diversity is found among the models in the simulated near surface absorption coefficients, particularly in regions associated with dust (e.g. Sahara, Tibet), biomass burning (e.g. Amazonia, Central Australia) and biogenic emissions (e.g. Amazonia). Regions associated with high anthropogenic BC emissions such as China and India exhibit comparatively good agreement for all models. Evaluation of modelled column AEs shows an underestimation of 9%+/-24% against AERONET and -21% against AATSR-SU. This suggests that models tend to overestimate particle size, with implications for lifetime and radiative transfer calculations. An investigation of modelled emissions, burdens and lifetimes, mass-specific-extinction coefficients (MECs) and optical depths (ODs) for each species and model reveals considerable diversity in most of these parameters. Inter-model spread of aerosol species lifetime appears to be similar to that of mass extinction coefficients, suggesting that AOD uncertainties are still associated to a broad spectrum of parameterised aerosol processes.

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